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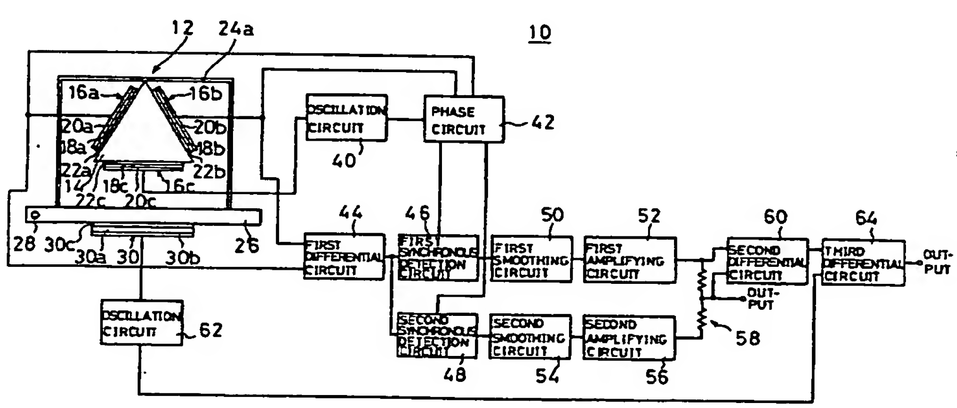
(54) Gyro-compass.

(57) A support base (26) of an angular velocity sensor (12) is supported rotatably at one end (28), and the support base (26) is vibrated by a piezoelectric element (30). By this vibration, a known rotational angular velocity is applied to the angular velocity sensor (12). For example, a difference of two output signals of the angular velocity sensor (12) is measured. This difference of the output signals is detected in synchronism with phases which differ from each other by 180°, in two synchronous detection circuits (46,48). The detected signal is smoothed in smoothing circuits (50,54), and further, amplified in amplifying circuits (52,56). An output signal of the amplifying circuit is composed in a variable resistor (58) as a composite circuit. Meanwhile, from the output signal of the amplifying circuit, the output signal of the variable resistor and a signal corresponding to the known rotational angular velocity are subtracted.

F I G. 1



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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing one embodiment of the present invention.

Fig. 2 is a side view showing a surroundings of an angular velocity sensor of a gyro-compass shown in Fig. 1.

Figs. 3(A)-3(G) are graphs showing output signals of respective circuits, when only a known rotational angular velocity is applied to an angular velocity sensor.

Figs. 4(A)-4(G) are graphs showing output signals of respective circuits, when a known rotational angular velocity and a linear velocity or acceleration are applied to an angular velocity sensor.

Figs. 5(A)-5(G) are graphs showing output signals of respective circuits, when a known rotational angular velocity and an external rotational angular velocity are applied to an angular velocity sensor.

Figs. 6(A)-6(G) are graphs showing output signals of respective circuits, when a known rotational angular velocity, a linear velocity or acceleration and an external rotational angular velocity are applied to an angular velocity sensor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a block diagram showing one embodiment of the present invention. A gyro-compass 10 includes an angular velocity sensor 12. As the angular velocity sensor 12, as shown in Fig. 1 and Fig. 2, for example, an vibration-type angular velocity sensor is used. The angular velocity sensor 12 includes a vibrator 14. The vibrator 14 is formed into a regular triangular columnar shape by, in general, a material generating mechanical vibration such as elinvar, iron-nickel alloy, quartz, glass, crystal, ceramics and the like.

At the center of three side faces of the vibrator 14, piezoelectric elements 16a, 16b and 16c are formed respectively. The piezoelectric element 16a includes a piezoelectric layer 18a, on both surfaces of which electrodes 20a and 22a are formed. One electrode 22a is bonded to the side face of the vibrator 14. Similarly, the piezoelectric elements 16b, 16c include piezoelectric layer 18b, 18c, on both surfaces of which electrodes 20b, 22b and electrodes 20c, 22c are formed. One electrodes 22b, 22c of the piezoelectric elements 16b, 16c are bonded to the side faces of the vibrator 14.

Meanwhile, the vicinity of nodal points of the vibrator 14 are supported by support members 24a and 24b consisting of, for example, a metal wire. The support members 24a and 24b are secured to the vicinity of the nodal points by, for example, welding. The support members 24a, 24b are secured to a support base 26. One end of the support base 26 is supported rotatably by a shaft 28. The shaft 28 is mounted so as to be parallel to an axial direction of the vibrator 14. Furthermore, on the lower face of the support base 26, a piezoelectric element 30 as angular velocity applying means is formed. The piezoelectric element 30 is consisting of a piezoelectric layer 30a and electrodes 30b, 30c formed on both surfaces of the piezoelectric layer 30a. By the piezoelectric element 30, the support base 26 vibrates reciprocally as drawing an arc about the shaft 28, and thereby the known rotational angular velocity is applied to the angular velocity sensor 12.

In the gyro-compass 10, among the piezoelectric elements 16a-16c of the angular velocity sensor 12, any two thereof are used for detection and these two or other one are used for driving. In this embodiment, the piezoelectric elements 16a and 16b are used for detection and driving, and the piezoelectric element 16c is used for feedback.

Between the driving piezoelectric elements 16a, 16b and the feedback piezoelectric element 16c, an oscillation circuit 40 and a phase circuit 42 are connected as a feedback loop for self-oscillation driving of the angular velocity sensor 12. A driving signal is given by the oscillation circuit 40 and the phase circuit 42, and the angular velocity sensor 12 is bent and vibrated in a direction orthogonal to a face whereon the piezoelectric element 16c is formed.

Furthermore, the detecting piezoelectric elements 16a, 16b are connected to a first differential circuit 44. In the first differential circuit 44, a difference between the outputs of the piezoelectric elements 16a and 16b is detected. The output of the first differential circuit 44 is inputted to a first synchronous detection circuit 46 and a second synchronous detection circuit 48. To the first synchronous detection circuit 46 and the second synchronous detection circuit 48, a synchronous signal is given from the phase circuit 42. In the first synchronous detection circuit 46 and the second synchronous detection circuit 48, in synchronism with the phases which differ from each other by 180°, the output signal of the first differential circuit 44 is detected.

The first synchronous detection circuit 46 is connected to a first smoothing circuit 50, in turn the first smoothing circuit 50 is connected to a first amplifying circuit 52. In the first smoothing circuit 50, an output signal of the first synchronous detection circuit 46 is smoothed, and the smoothed signal is amplified in the first amplifying circuit 52. Similarly, the second synchronous detection circuit 48 is connected to a second smoothing circuit 54, in turn, the second smoothing circuit 54 is connected to a second amplifying circuit 56. In the second smoothing circuit 54, an output signal of

44 becomes a waveform signal moved to the positive side from 0V as shown in Fig. 4 (A). Since the rotational angular velocity is not applied to the angular velocity sensor 12 from the outside, an amplitude of the output signal of the first differential circuit 44 is same as that shown in Fig. 3 (A). This output signal is detected in synchronism with phases which differ from each other by 180°, in the first synchronous detection circuit 46 and the second synchronous detection circuit 48. That is, in the first synchronous detection circuit 46, as shown in Fig. 4 (B), the positive side of the output signal of the first differential circuit 44 is detected. In the second synchronous detection circuit 48, as shown in Fig. 4 (C), the negative side of the output signal of the first differential circuit 44 is detected. When these signals are smoothed in the first smoothing circuit 50 and the second smoothing circuit 54, and amplified in the first amplifying circuit 52 and the second amplifying circuit 56, as shown in Fig. 4 (D) and Fig. 4 (E), a high voltage is outputted from the first amplifying circuit 52, and a low voltage is outputted from the second amplifying circuit 56. When these signals are composed in the variable resistor 58, as shown in Fig. 4 (F), an output corresponding to the linear velocity or acceleration is obtained from its output terminal.

In the second differential circuit 60, the output signal of the variable resistor 58 is subtracted from the output signal of the first amplifying circuit 52. Therefore, from the second differential circuit 60, a signal obtained by subtracting the signal by the linear velocity or acceleration applied to the angular velocity sensor 12, from the output signal of the first amplifying circuit 52 is outputted. This signal is a signal corresponding to the known rotational angular velocity applied to the angular velocity sensor 12. Thus, when the signal corresponding to the known rotational angular velocity is subtracted in the third differential circuit 64, the output from the third differential circuit becomes zero. Thereby, it is clear that the rotational angular velocity is not applied to the angular velocity sensor 12 from the outside.

Next, a case where the rotational angular velocity is applied to the angular velocity sensor 12 from the outside is considered. In this case, since the known rotational angular velocity is applied to the angular velocity sensor 12, by the rotational angular velocity from the outside, for example, a voltage generated in the piezoelectric element 16a becomes larger and a voltage generated in the piezoelectric element 16b becomes smaller. Therefore, an amplitude of the output signal of the first differential circuit 44 become larger as compared with the case where only the known rotational angular velocity is applied, as shown in Fig. 5 (A). This signal is detected in synchronism with the phases which differ from each other by 180°, in the first synchronous detection circuit 46 and the second synchronous detection circuit 48. Thus, the output signal of the first synchronous detection circuit 46 becomes a positive side signal centering around 0V, as shown in Fig. 5 (B). The output signal of the second synchronous detection circuit 48 becomes a negative side signal centering around 0V, as shown in Fig. 5 (C). When these signals are smoothed in the first smoothing circuit 50 and the second smoothing circuit 54, and further, amplified in the first amplifying circuit 52 and the second amplifying circuit 56, as shown in Fig. 5 (D) and Fig. 5 (E), the signals which are in opposite direction with each other and having the same strength are outputted. When these-signals are composed in the variable resistor 58, the output of the variable resistor 58 becomes zero. Thereby, it is clear that the linear velocity or acceleration is not applied to the angular velocity sensor 12.

In the second differential circuit 60, though the output signal of the variable resistor 58 is subtracted from the output signal of the first amplifying circuit 52, since the output of the variable resistor 58 is zero, the output signal of the first amplifying circuit 52 is outputted from the second differential circuit 60 as it is. In this output signal, signals corresponding to the known rotational angular velocity applied to the angular velocity sensor 12 and the rotational angular velocity applied from the outside are included. Thus, when the signal corresponding to the known rotational angular velocity is subtracted in the third differential circuit 64, as shown in Fig. 5 (G), only the signal corresponding to the rotational angular velocity applied from the outside is outputted. From this signal, the rotational angular velocity applied to the angular velocity sensor 12 from the outside can be known.

Next, a case where both the external rotational angular velocity and the linear velocity or acceleration are applied to the angular velocity sensor 12 from the outside is considered. In this case, from the first differential circuit 44, as shown in Fig. 6 (A), an output signal which has a larger amplitude than the case where, for example, only the known rotational angular velocity is applied, and moves to the positive side from 0V is obtained. This signal is detected in synchronism with the phases which differ from each other by 180°, in the first synchronous detection circuit 46 and the second synchronous detection circuit 48. Thus, from the first synchronous detection circuit 46, as shown in Fig. 6 (B), a positive side voltage is outputted. From the second synchronous detection circuit 48, as shown in Fig. 6 (C), a negative side voltage is outputted. These signals are smoothed in the first smoothing circuit 50 and the second smoothing circuit 54, and further, amplified in the first amplifying circuit 52

2. A gyro-compass in accordance with claim 1, wherein by detecting the output signal of said angular velocity sensor at the phase difference of 180° respectively in said plurality of synchronous detection circuits, a positive portion and a negative portion of the output signal of said angular velocity sensor are detected.

3. A gyro-compass in accordance with claim 1, wherein said composite circuit is a variable resistor.

4. A gyro-compass in accordance with claim 1, wherein said angular velocity applying means includes piezoelectric elements for giving vibration drawing a circular to said angular velocity sensor, and an oscillation circuit for driving said piezoelectric elements, and a signal corresponding to a known rotational angular velocity is obtained by smoothing an output signal of said oscillation circuit.

5. A gyro-compass in accordance with claim 1, wherein said angular velocity sensor is a vibrating gyroscope utilizing bending and vibrating movement of a columnar vibrator.

6. A gyro-compass in accordance with claim 5, wherein said vibrating gyroscope includes said vibrator of triangular columnar shape and piezoelectric elements formed on the side faces of said vibrator.

7. A gyro-compass in accordance with claim 5, wherein a difference of output signals obtained from two piezoelectric elements among said piezoelectric elements formed on said vibrating gyroscope is inputted to said synchronous detection circuits.

8. A gyro-compass in accordance with claim 5, wherein said vibrating gyroscope is bent and vibrated by a driving circuit consisting of an oscillation circuit and a phase circuit, and a signal for synchronous detection is applied to said synchronous detection circuit from said phase circuit.

F I G. 2

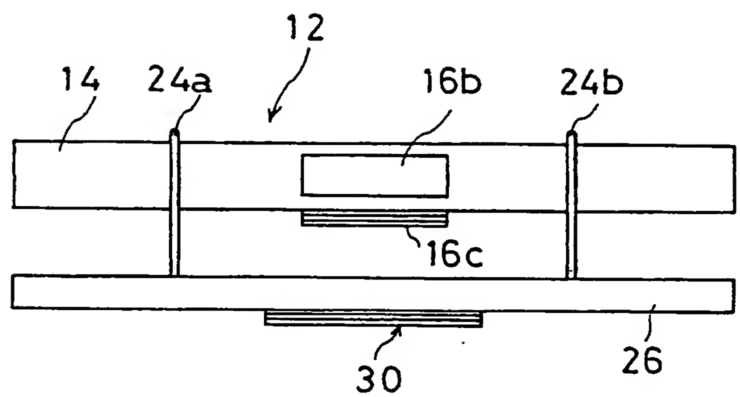


FIG. 4 (A)

OUTPUT OF FIRST DIFFERENTIAL CIRCUIT 44

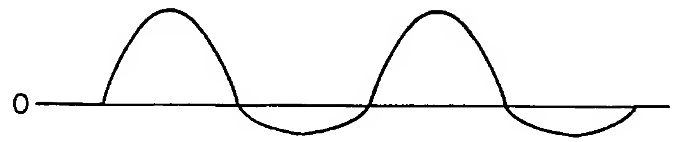


FIG. 4 (B)

OUTPUT OF FIRST SYNCHRONOUS DETECTION CIRCUIT 46

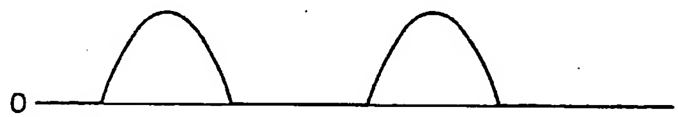


FIG. 4 (C)

OUTPUT OF SECOND SYNCHRONOUS DETECTION CIRCUIT 48

FIG. 4 (D)

OUTPUT OF FIRST AMPLIFYING CIRCUIT 52

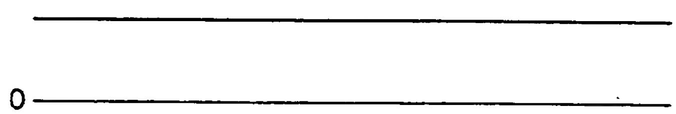


FIG. 4 (E)

OUTPUT OF SECOND AMPLIFYING CIRCUIT 56

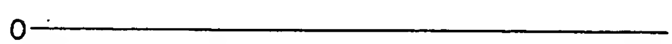


FIG. 4 (F)

OUTPUT OF VARIABLE RESISTOR 58

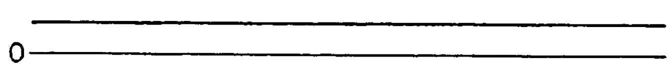
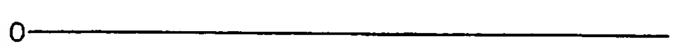


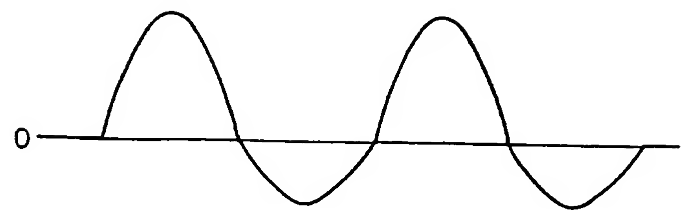
FIG. 4 (G)

OUTPUT OF THIRD DIFFERENTIAL CIRCUIT 64



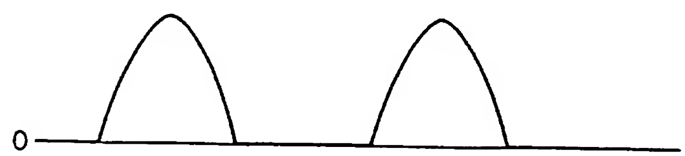
F I G. 6 (A)

OUTPUT OF FIRST
DIFFERENTIAL CIRCUIT 44



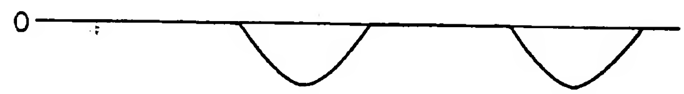
F I G. 6 (B)

OUTPUT OF FIRST
SYNCHRONOUS DETECTION
CIRCUIT 46



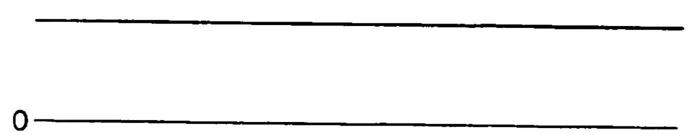
F I G. 6 (C)

OUTPUT OF SECOND
SYNCHRONOUS DETECTION
CIRCUIT 48



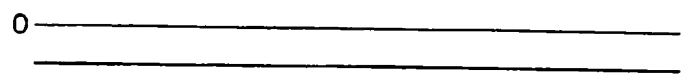
F I G. 6 (D)

OUTPUT OF FIRST
AMPLIFYING CIRCUIT 52



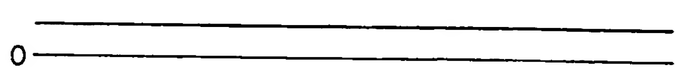
F I G. 6 (E)

OUTPUT OF SECOND
AMPLIFYING CIRCUIT 56



F I G. 6 (F)

OUTPUT OF VARIABLE
RESISTOR 58



F I G. 6 (G)

OUTPUT OF THIRD
DIFFERENTIAL CIRCUIT 64